AN IMPROVED ULTRASONIC IMAGE PRESENTATION

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INTRODUCTION

NDE technology encompasses a broad field of applications [1] such as material selection, properties characterization, defect detection, damage assessment, process monitoring, in-service sensing, etc. However, the most common application of NDE, for hardware manufacturers, remains in quality assurance of products at various check points. In such operations, process engineers and customers demand well archived inspection procedures and test records for future reference. Although inspection reports may serve this purpose, imaging techniques that directly correlate measured NDE parameters with specimen coordinates are the preferred methods for inspection and data presentation.

In recent years, advancements in computer hardware, software, and peripheral electronics technology have facilitated the development and improvement of NDE inspection systems. Consequently, many ultrasonic imaging systems, with varying degrees of sophistication, have been devised [2-4]. The basic ultrasonic imaging system plots proportional gated RF amplitude with respect to each sampling coordinate. More elaborate ultrasonic imaging systems digitize and acquire entire A-scan waveform at all sampling positions for versatile post-scan signal processing and data manipulations [5].

There are three basic schemes of ultrasonic image acquisition and presentation, namely B-scan, C-scan, and Time-Of-Flight (TOF). The acquired ultrasonic signals are typically processed and presented in one of the following forms of visualization: grayscale, false-color, 3-D mesh, or the combination of mesh and grayscale or false-color images. Since there are no natural colors associated with the ultrasonic signals, false-color pallets are assigned to represent different bands of signal amplitude to enhance the image. In any of the above listed forms of image presentation, a single image can only display one measured parameter. We have developed an unique data acquisition and image processing system that enables the presentation of two ultrasonic parameters in a single image. In this paper, we will review the principle of operation, describe the hardware and software configurations, and demonstrate this improved ultrasonic image presentation method.

In modern applications, multiple NDE methods and techniques are often required to obtain various aspects of materials and defect properties of a hardware component. The new operation promotes an emerging area of NDE research interest in data fusion and integration. The objective is to consolidate all pertinent NDE information and convey the result to other engineering disciplines in a comprehensive manner. Also, advanced concurrent engineering requires active integration of various manufacturing procedures into one harmonious process. It is thus necessary to convey all engineering information among each other in a common platform, namely specimen coordinates. The method that combines two distinct ultrasonic parameters in one image represents a simple example of data fusion.

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BACKGROUND AND APPROACH

First generation C-scan systems were based totally on analog technology. The images were generated by a current-driven pen across a special carbon paper. State-of-the-art systems are based on digital technology, with data storage and signal processing capabilities. After the signals have been acquired by the computer, they can be manipulated in many different ways. Typically, there are three methods with which to present ultrasonic C-scan data: grayscale, false-color and 3-D mesh images. Nevertheless the principle of image presentation is to transfer ultrasonic C-scan data to a display, where it can be expressed as: C-scan (x, y, amplitude (x, y)) --> Display (x', y', indicator). Where (x, y) are the specimen coordinates and (x', y') are the display coordinates. It is relatively easy to convert the range of ultrasonic data to a corresponding range of display indicators such as grayscale.

In our approach, besides acquiring amplitude information, we also simultaneously acquire TOF information for each (x, y) sampling point. In this case, the transformation can be written as: C-scan (x, y, amplitude(x, y), TOF(x, y)) --> Display (x', y', indicator1, indicator2). The idea of using a line drawing to display specimen geometry and using color or grayscale to display associate information is not new. Many finite element analysis software packages have used color to display different stress intensities on a 3-D mesh component model. Other graphic software packages also use color or grayscale to enhance 3-D mesh data drawings. Since TOF is a form of specimen depth information, we can use a 3-D mesh to display (x, y, TOF) and use color or grayscale to display amplitude. However, it is necessary to devise appropriate hardware and software for a typical ultrasonic C-scan system in order to utilize the described concept for a combined amplitude and TOF image.

We have configured and integrated an advanced ultrasonic C-scan imaging system with an enhanced signal acquisition, data archive/retrieval and image generation software routines [6]. The block diagram of this improved amplitude and TOF C-scan imaging system is shown in Figure 1. The hardware of the improved system is similar to an upgraded off-the-shelf ultrasonic C-scan imaging system that consists of a system controller, a X-Y mechanical scanner, an ultrasonic pulser/receiver, a gate-peak-detector, two stepless timing gates and a timer/counter. The X-Y scanner is programmed to move in a raster fashion using a motion controller. The scanner enables the transducer which is mounted on the Z-axis and perpendicular to the specimen surface, to relatively scan the specimen over the area of interest of the specimen. Gate-peak-detected amplitude signal and TOF measurement at each X-Y sampling position are acquired and stored for image generation.

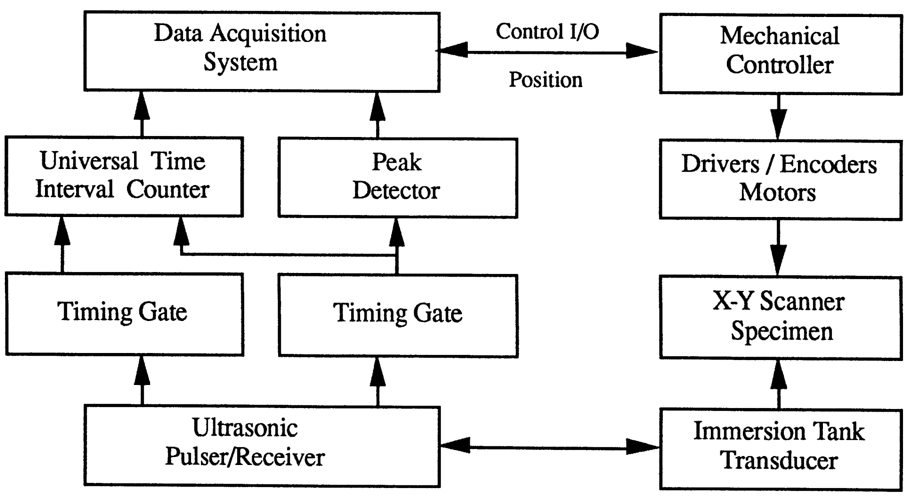

Figure 1. Block diagram of the ultrasonic amplitude and time-of-flight C-scan imaging system configuration.

In our specific ultrasonic C-scan system configuration, an IBM-386 compatible PC is used as the system controller. Software routines have been developed for scan control, signal acquisition, data archiving and image generation. An ultrasonic pulser/receiver is used to transmit and receive signals from a 1/4 inch 10 MHz transducer. A stepless timing gate is set to follow the front surface pulse and the gate width is set to cover the area between the front surface and back surface, including the back surface. An X-Y scanning table, and a Plexiglas water tank form the mechanical subsystem.

The gate peak detected amplitude is acquired from a digital multi-meter and the TOF is acquired from a digital timer/counter through the IEEE-488 interface bus. The measured TOF of the defect indication is referenced to the front surface and can be easily converted to represent the depth of the defect from the surface. The amplitude and TOF data of each scanning coordinate are stored in a computer data file with sequential data stream architecture. A unique image processing algorithm was developed to retrieve the data from the file, process the acquired data, and produce a combined amplitude/TOF C-scan image.

LABORATORY EXPERIMENTS AND RESULTS

To demonstrate the concept of combining two measured ultrasonic parameters, a unique test specimen was conceived and fabricated. The test piece, a 3.5" long by 2.0" wide by 1/4" high aluminum plate, with six 5/16" diameter pegs is shown in Figure 2. The pegs are of various lengths to simulate defects of various depths in the material. The surfaces of the pegs were crafted to produce non-uniform reflections.

For the experiments, the water path was set to 2" above the top surface of the base to give the height of the specimen. The mechanical scan speed was set to 0.1 inch/sec. The stepless timing gate was set to include the area between the main pulse and the base, including the base. The reflected pulse within the timing gate amplitude is digitized and transmitted to the computer as the amplitude measurement. The sampling increments were set to 0.01" for both the X- and Y-axis. The main pulse was used as the start trigger and the gated RF pulse was used as the stop trigger for the timer/counter is order to obtain the TOF measurement.

After a scan is completed, an image generating routine is executed to produce a graphic display of the acquired data set. With (x, y) position and Z(x, y) [Z(x, y)= TOF(x, y)/2 · velocity], a 3-D mesh drawing of detected flaws is displayed. For each (x, y) point, the pixel is assigned with a grayscale or false-color value based on the proportional amplitude at this position. Figure 3 is the resulting combined ultrasonic amplitude and TOF C-scan image of the test specimen.

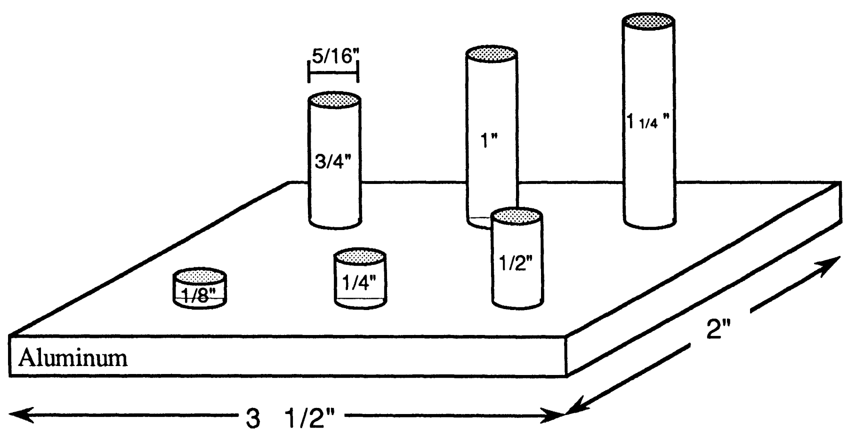

Figure 2. A sketch of the test specimen simulating the defects in a material.

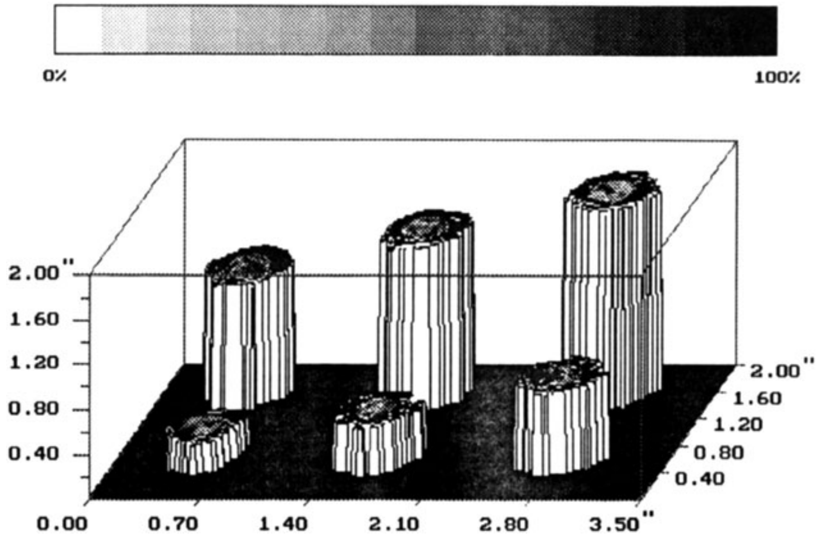

Figure 3. A combined ultrasonic amplitude and TOF C-scan image of the 3.5" x 2" x 2" test specimen.

CONCLUSION AND DISCUSSION

As it can be seen from Figure 3, the improved C-scan image directly correlates both ultrasonic amplitude and TOF data with the specimen geometry. The apparent defect parameters such as depth, size and shape can be estimated. Engineers can easily interpret the inspection result and identify anomalies associated with the specimen to determine the integrity of the structure. The inspection can be incorporated as part of a concurrent engineering process.

In summary, we have presented a noble approach for a combined ultrasonic amplitude and TOF C-scan image using 3-D mesh and grayscale (or false-color). We have configured and integrated an improved ultrasonic C-scan imaging system based on off-the-shelf instruments. A unique specimen has been designed and fabricated for the experiments. Laboratory experiments have demonstrated the approach.

The advanced concurrent engineering concept emphasizes consolidation of all pertinent engineering practices including NDE. This approach prompts two areas of interest for research namely data integration and data fusion. The approach of combining ultrasonic amplitude and TOF measurements represents a simple example of data fusion.

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